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CHARACTERIZATION OF TEMPERATURE DEPENDENT INDEX OF REFRACTION AND THERMO-OPTIC COEFFICIENT FOR InAs AND InSb (PREPRINT)

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Survivability and Sensor Materials Division

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14. ABSTRACT
We demonstrate the use of interferometric techniques to measure the temperature dependence of the index of refraction and thermo-optic coefficient of infrared wafer-shaped optical materials, and report our results for InAs and InSb.

15. SUBJECT TERMS
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Characterization of temperature dependent index of refraction and thermo-optic coefficient for InAs and InSb

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Abstract: We demonstrate the use of interferometric techniques to measure the temperature dependence of the index of refraction and thermo-optic coefficient of infrared wafer-shaped optical materials, and report our results for InAs and InSb.

Introduction

Despite the importance of small bandgap materials such as InAs and InSb in many infrared applications, accurate values of their refractive indices, dispersions, and thermo-optic coefficients are not easily available in the literature.

The traditional minimum deviation method for measuring the refractive index and thermo-optic coefficients of materials cannot be applied to wafer-shaped materials having flat-parallel surfaces. In the past, non-destructive refractive index measurements have been performed for wafer-shaped infrared materials at room and cryogenic temperatures using a modified Michelson interferometer [1].

Here we demonstrate how an angle-dependent Michelson/Fabry-Perot interferometer, a temperature-dependent Fabry-Perot interferometer, and a temperature-dependent laser micrometer may be used to accurately measure the temperature dependent index of refraction and thermo-optic coefficient of wafer-shaped optical materials. The accuracy of the method is first determined by measuring the optical parameters of Ge and Si and comparing with the well accepted values. We report here the results for InAs and InSb measured at a wavelength of 10.61 μm. The measurements are performed using no previous knowledge of the material and are non-destructive in nature.

Method

Following the method outlined in reference [2], the absolute refractive index and thickness of a parallel wafer can be independently determined using a combination of Michelson and Fabry-Perot interferometry. In this method the sample is rotated in the beam path within the interferometer and the phase information is recorded as a function of the sample's angular orientation. The phase information is extracted from the observed interferences with respect to a reference beam, or due to multiple internal reflections within the sample for Michelson and Fabry-Perot interferometry, respectively. The difference between the phase information of the two interferometric techniques yields the sample materials thickness using the relation

$$\phi_m(\theta) - \phi_f(\theta) = \frac{4\pi L}{\lambda}(1 - \cos\theta),$$

where L is the materials thickness at the point of interest, λ is the probe laser wavelength, and θ is the angle of the normal of the sample surface with respect to the incident laser [2]. Once the thickness at the point of interest is determined, the refractive index for the given temperature can be determined from the phase information from either interferometric methods. The temperature dependence of the sample's thickness is measured using a laser micrometer while the sample is mounted in a temperature-controlled dewar.

The phase change of the optical beam path for a single-pass Fabry-Perot interferometer is given by $\phi(T) = 4\pi L(T)n(T)/\lambda$. Using the previously determined function of $L(T)$, the temperature dependence of the refractive index can be determined.

Results

The index of refraction and thermo-optic coefficient were measured for the approximate temperature ranges of 100 to 350 K for Ge, Si, InAs, and 100 to 225 K for InSb. The thermal expansion coefficients and thermo-optic coefficients of Ge and Si have been previously well documented for the temperature range 98-298 K and were used to verify our methods and results [3]. Figure 1 shows a typical result for the index of refraction vs. temperature for InAs. Figure 2 illustrates the thermo-optic coefficient vs. temperature for InAs. We will present the results of n vs. T and dn/dT vs. T for a variety of infrared materials including InAs and InSb. To the authors' knowledge these are the first reported sample-specific results of the thermo-optic parameters for wafer-shaped infrared materials and the first experimentally reported results for InAs and InSb across the noted temperature ranges.

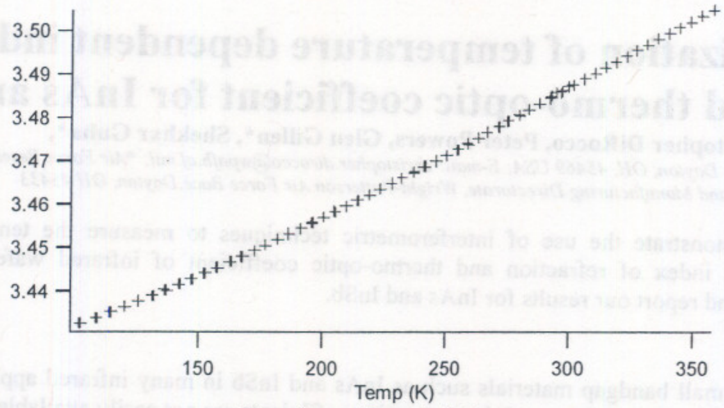

Figure 1: n vs. Temp for InAs

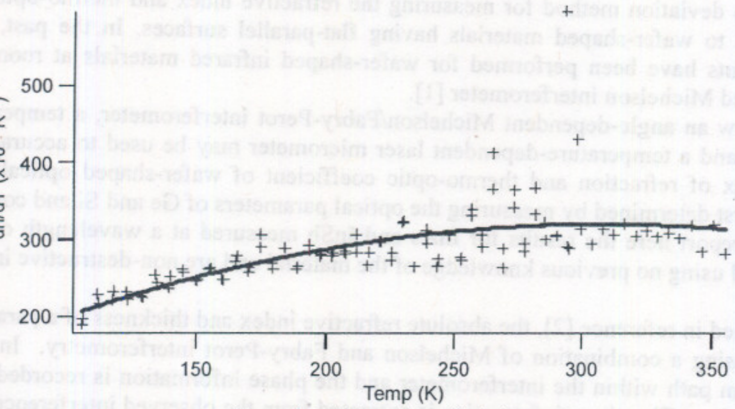

Figure 2: dn/dT vs. Temp for InAs

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3. H. W. Icenogle, B. Platt, and W. Wolfe, "Refractive indexes and temperature coefficients if germanium and silicon", Appl. Opt. **15**, 2348-2352 (1976).